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Analysis of the Operational Effect of the Joint Chemical Agent Detector Using the Infantry Warrior Simulation (IWARS)

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Purpose

- Integrate chemical agent and defense capabilities into a combat simulation in order to derive quantitative Measures of Effectiveness
- Use to support CBD systems evaluations
  - JCAD Inc. 1 as test case
  - Comparitive analysis against current capabilities

IWARS Introduction

Infantry WARrior Simulation (IWARS):

- A M&S tool for conducting Infantry Soldier Analyses, developed jointly by AMSAA and the Natick Soldier Center
- Focuses on dismounted individuals, small units, and their equipment for assessing operational effectiveness across the spectrum of missions, threats and environments
- Development heavily influenced by Army analysis needs (e.g., Land Warrior Program)

IWARS combines:
- Soldier equipment
- Soldier behaviors
- Algorithms and data

IWARS is:
- Constructive
- Agent-based
- Multi-sided
- Focused on soldiers and small-units

IWARS Development:

- Version 1.0 approved May 2006 for:
  - Small Arms Analysis
  - Sensor Analysis
  - Lethality/Survivability Analysis
  - Limited Battle Command Analysis
- Continually integrating best available methodology/data

IWARS Supports a Range of Individual and Small-Unit Analyses

The Joint Chemical Agent Detector

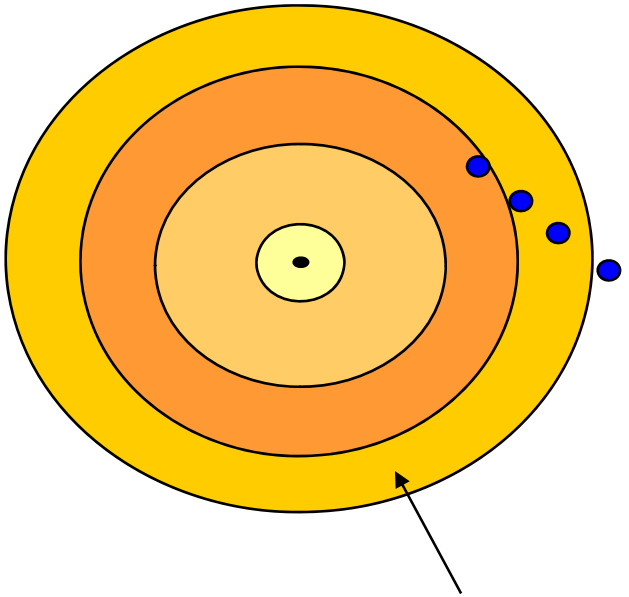
- Lightweight and portable chemical agent detector
  - About 2 lb and 45 in.^{3}
- Unobtrusive
- Visual and audio alarms
- Uses
  - Fixed or mobile platforms
  - Survey instrument
- Incremental development (Incr. 1 shown)

Integration of Chemical Effects into IWARS

- **Modification of IWARS**
  - Chemical agent vapor plume modeling
  - Detector alert responses
  - CBD system performance integration
  - Soldier CB response behaviors/tactics
  - Code alteration
  - Toxological level modeling
- **Data Collection**
  - External modeling plume using HPAC
  - Scenario design w/ SMEs
  - Verification and Validation
  - Requirements data presented
- **Production Runs**
- **Documentation**
  - V&V Plan and Report
  - Event Design Plan
  - Analysis Report

IWARS Chemical Agent Hazard Integration

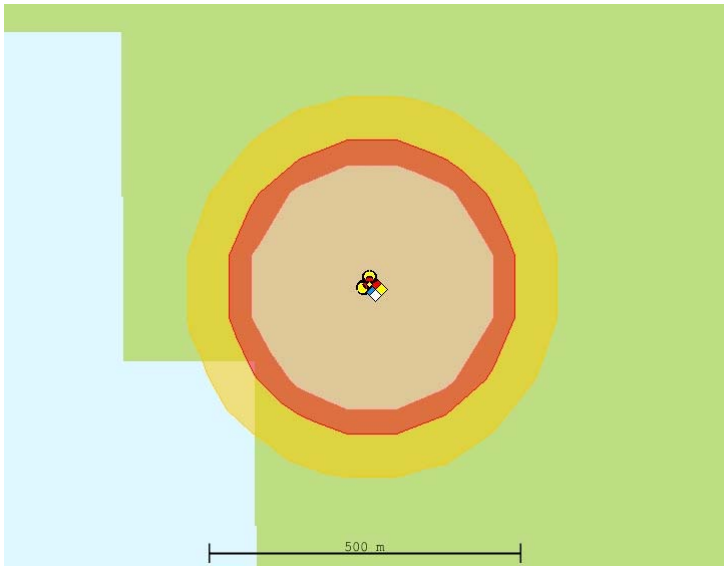
- Use existing IWARS spherical smoke cloud methodology
- Edge of sphere used to trigger Soldier behaviors/effects inside chemical plume
- Time and range from center of cloud used to determine concentration ring
- Concentric rings each have a different concentration level, yet uniform within
- File created describing the p(detect) for different concentration levels (based on JCAD requirements)
- Detector alerts if random draw meets p(detect) value
- Cloud parameters (expansion rate, wind speed, wind direction) are data driven



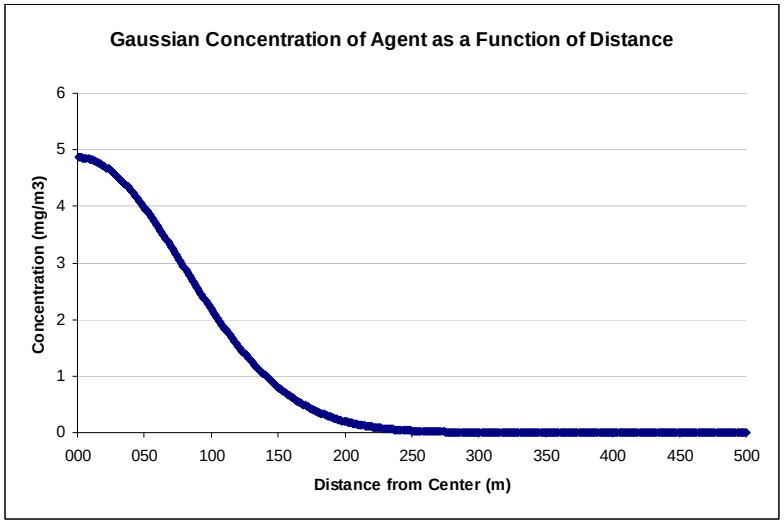
External Vapor Hazard Concentration Modeling

1. Agent Cloud modeled in HPAC offline
   - No wind or terrain effects
2. Data collected
   - Maximum concentration
   - Distance from center to 0.004 mg/m^3 (AEGL-1)
3. Gaussian distribution adjusted to match maximum concentration and distance to AEGL-1 level
4. Concentration per meter from the center of mass of the cloud exported to IWARS

1st Order Approximation



HPAC output of agent cloud at 5 minutes



Concentration of agent vs distance at 5 minutes

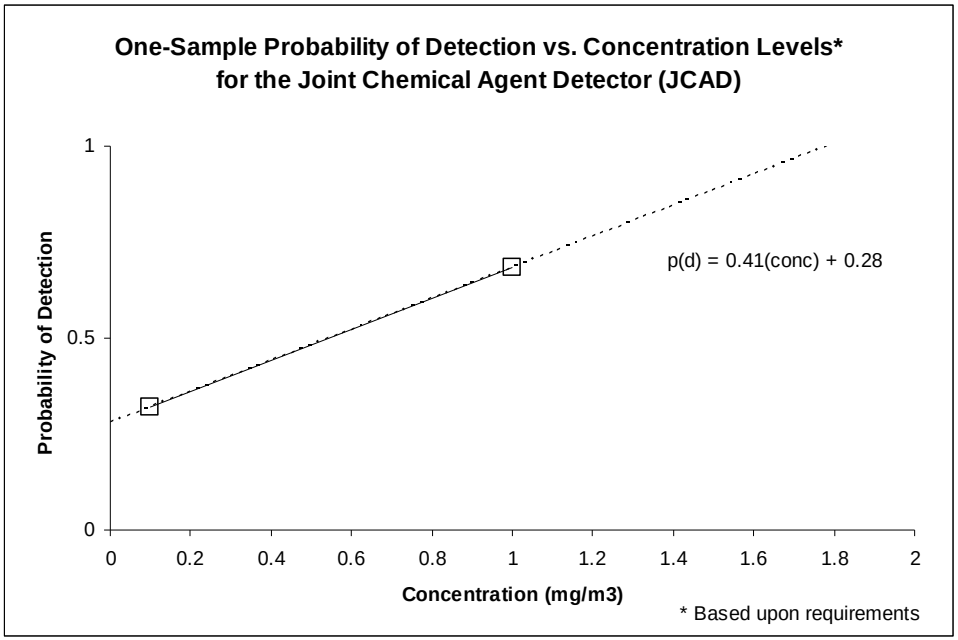
Single-Sample (every 5 sec) Detection Probability

- Example data:
  - $P(d)_{cum}$=0.9, 30 sec response time at 0.1 mg/m^3
  - $P(d)_{cum}$=0.9, 10 sec response time at 1.0 mg/m^3
- Equation for single sample (every 5 sec) p(d) derived
  - $p(d) = 1.0 - \sqrt[S]{1.0 - p(d)_{cum}}$
- Linear function generated from given data

Sample Calculations for 0.1 mg/m^3

Sample Interval = 5.0 sec
p(d) cumulative = 0.9
Response Time = 30.0 sec
Samples per time (s) = 30.0 / 5.0 = 6

$$p(d) = 1.0 - \sqrt[6]{1.0 - 0.9} = 0.319$$



V&V of Chemical Modifications

Verification tests

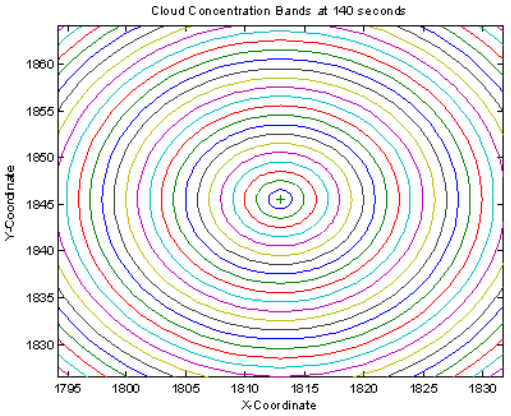
- Chemical cloud
  - Creation, expansion, movement with wind, dissipation
  - Concentration band determination
- Alert device
  - Operating modes (survey, monitor) and audible range
  - Probability of detection and false alarm rate
- Soldier entity
  - Accumulation and reaction to chemical agent dosages
  - Use of protective gear to limit exposure time and level
  - Degraded mobility, acquisition, delivery accuracy in protective gear

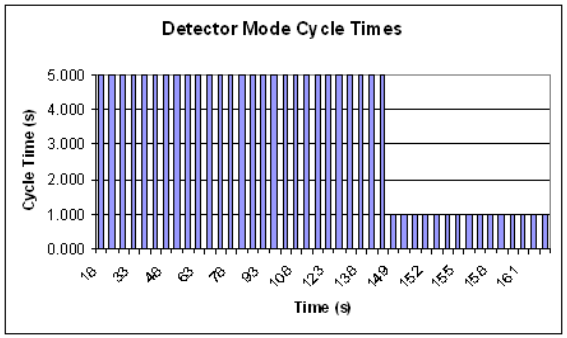
Sensitivity runs

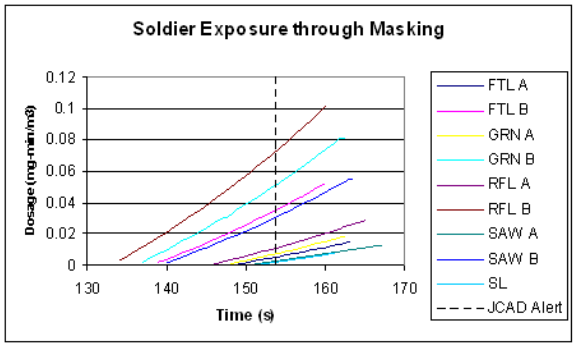
- Detector performance (50% decrease, 50% increase)
- False alarm rate (probabilities: 0.25, 0.50)
- Chemical agent susceptibility (50% decrease, 50% increase)
- Masked audible range (50% decrease, 100% increase)

Sample study

- 5 cases combine chemical agent use, MOPP gear, JCAD
- Results assess mission completion rate, mission time, small-arms losses, exposure level, exposure time

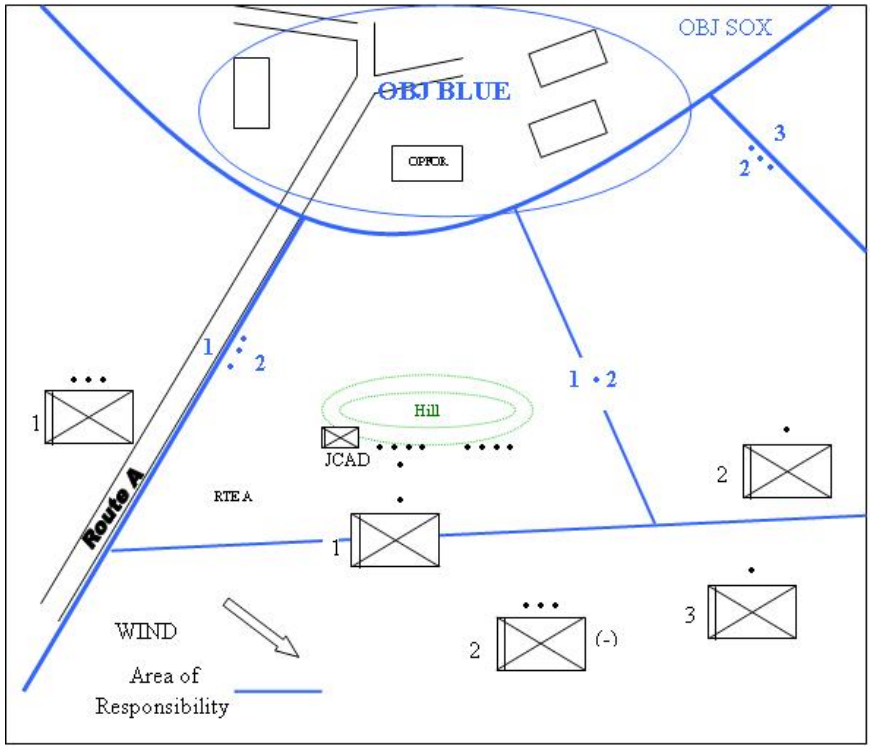






Scenario

- Infantry Battalion assault on OBJ SOX
  - A Company to secure OBJ BLUE
    - 1st Platoon: Secure Route A, then building west of Route A in OBJ BLUE
    - 2nd Platoon: Provide supporting fire to 1st Platoon. After 1st Platoon has secured Route A assault to secure buildings east of Route A in OBJ BLUE
    - 3rd Platoon: Reserve (not shown)
- Threat
  - OPFOR has not used chemical agents in past; capability limited to isolated recovered munitions
  - OBJ SOX may contain an IED production site
  - BLUEFOR starts in MOPP level 2, assumes MOPP level 4 upon alarm or onset of symptoms; auto-masking for artillery/mortars
  - OPFOR previously emplaced an IED near Route A (mistakenly used old, unmarked 152mm chemical round)
- Environment
  - Nominal Temperature
  - Neutral Air Stability
  - Wind: 1 m/s SE

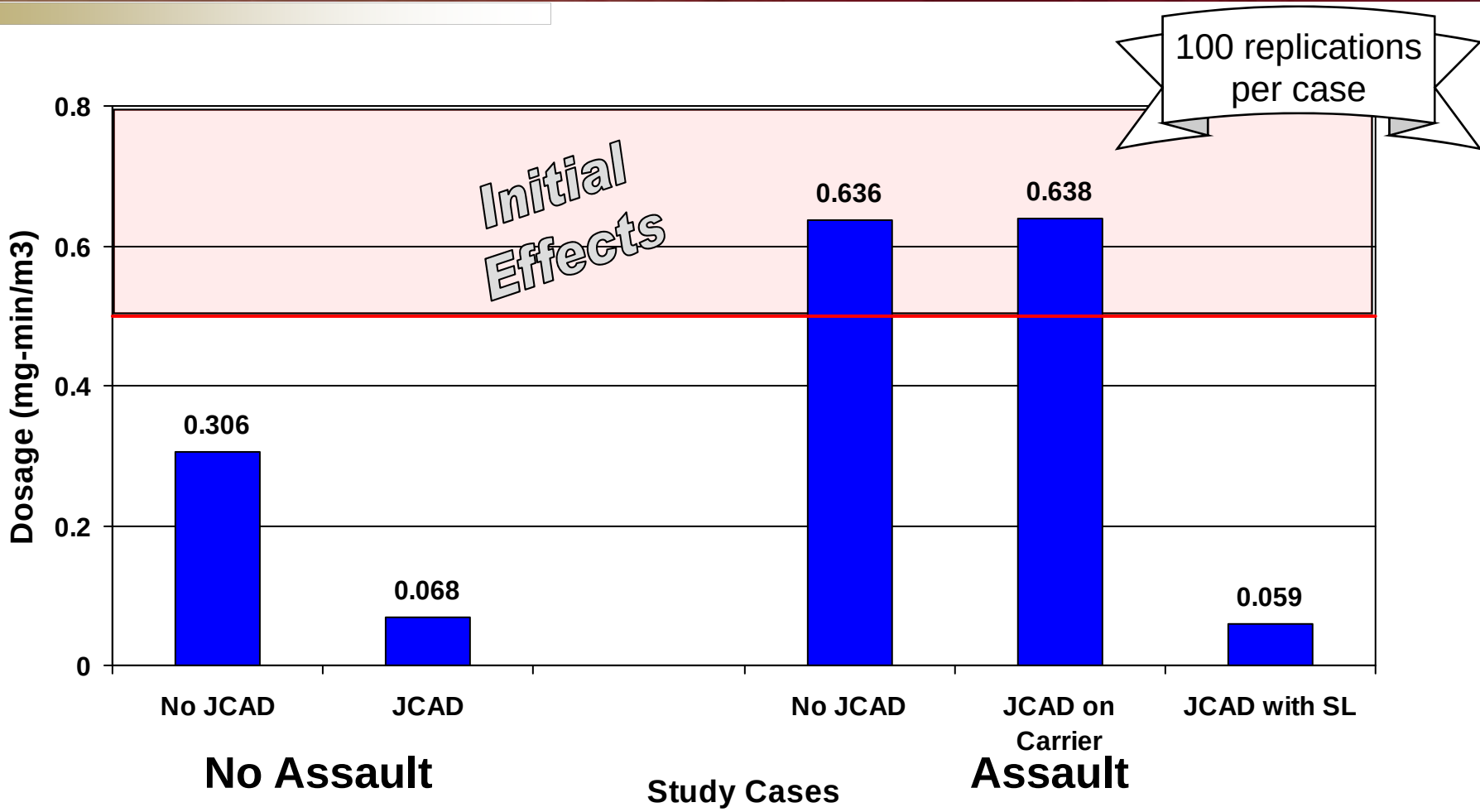


* Coordinated w/ US Army CBRN School, MANSCEN

Scenario: Production Runs

	Case #	Short Description	Description
Primary	1	Baseline without JCAD	Squad will move to the top of the hill and wait (will engage OPFOR from the top of the hill). In response to a chemical agent alert, Soldiers assume MOPP 4 and withdraw to starting point.
	2	Baseline with JCAD	Same as case #1, except: JCAD mounted to carrier.
Alternate Cases	3	Assault, No JCAD	Squad will begin assault of OPFOR building after IED detonation. When chemical symptoms are recognized, Soldiers will assume MOPP 4 and continue the assault. There will be no JCAD.
	4	Assault, JCAD on Squad Carrier	Same as case #3, except: JCAD mounted to squad carrier and operated continuously.
	5	Assault, JCAD carried by squad	Same as case #3. Squad leader will carry the JCAD during the assault.

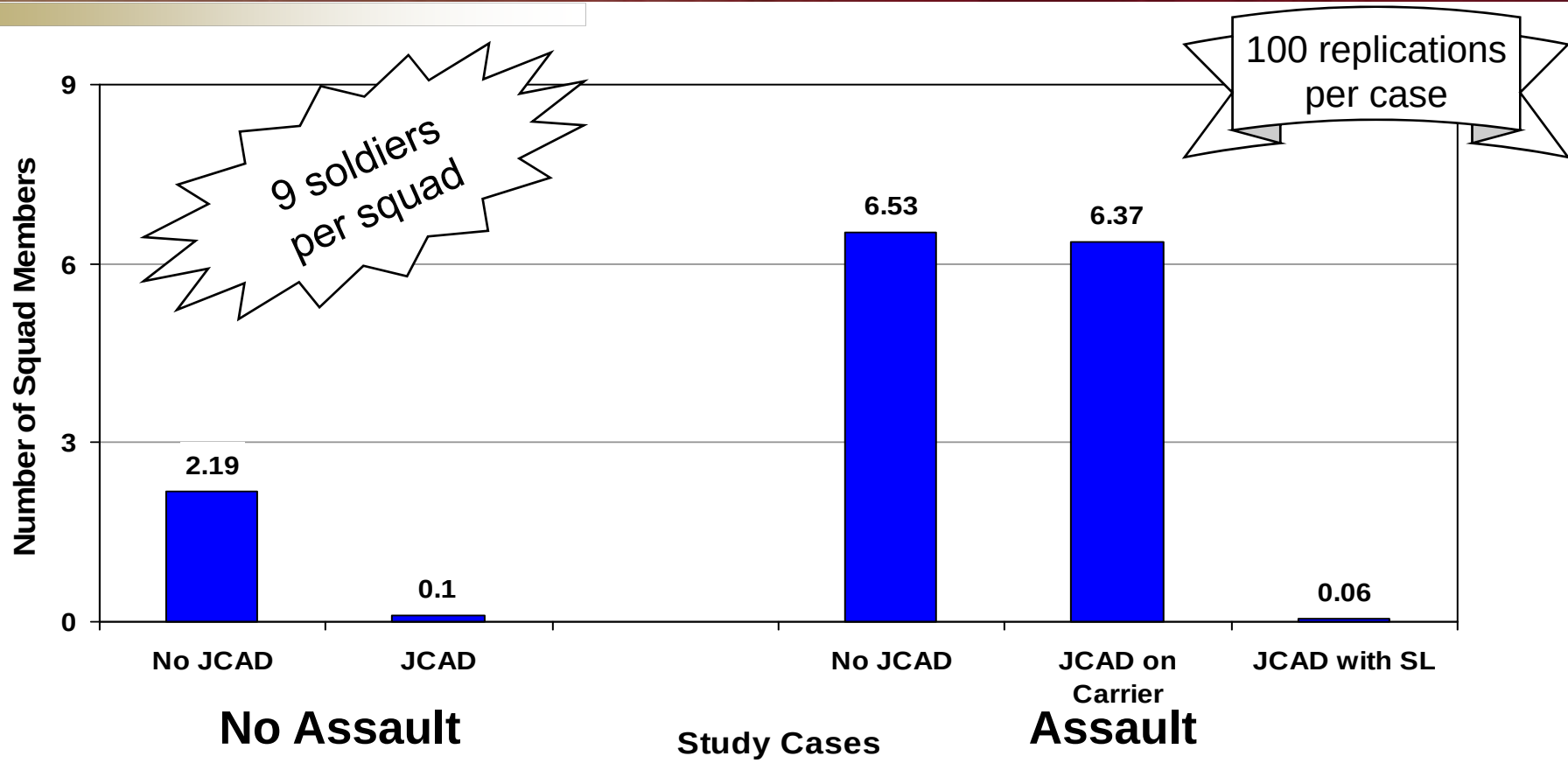
Results: Average BLUEFOR CWA Dosage



- No Assault: Significant* Reduction (78%) with JCAD
- Assault: Significant* Reduction (91%) only with JCAD on Squad leader

* 95% Confidence

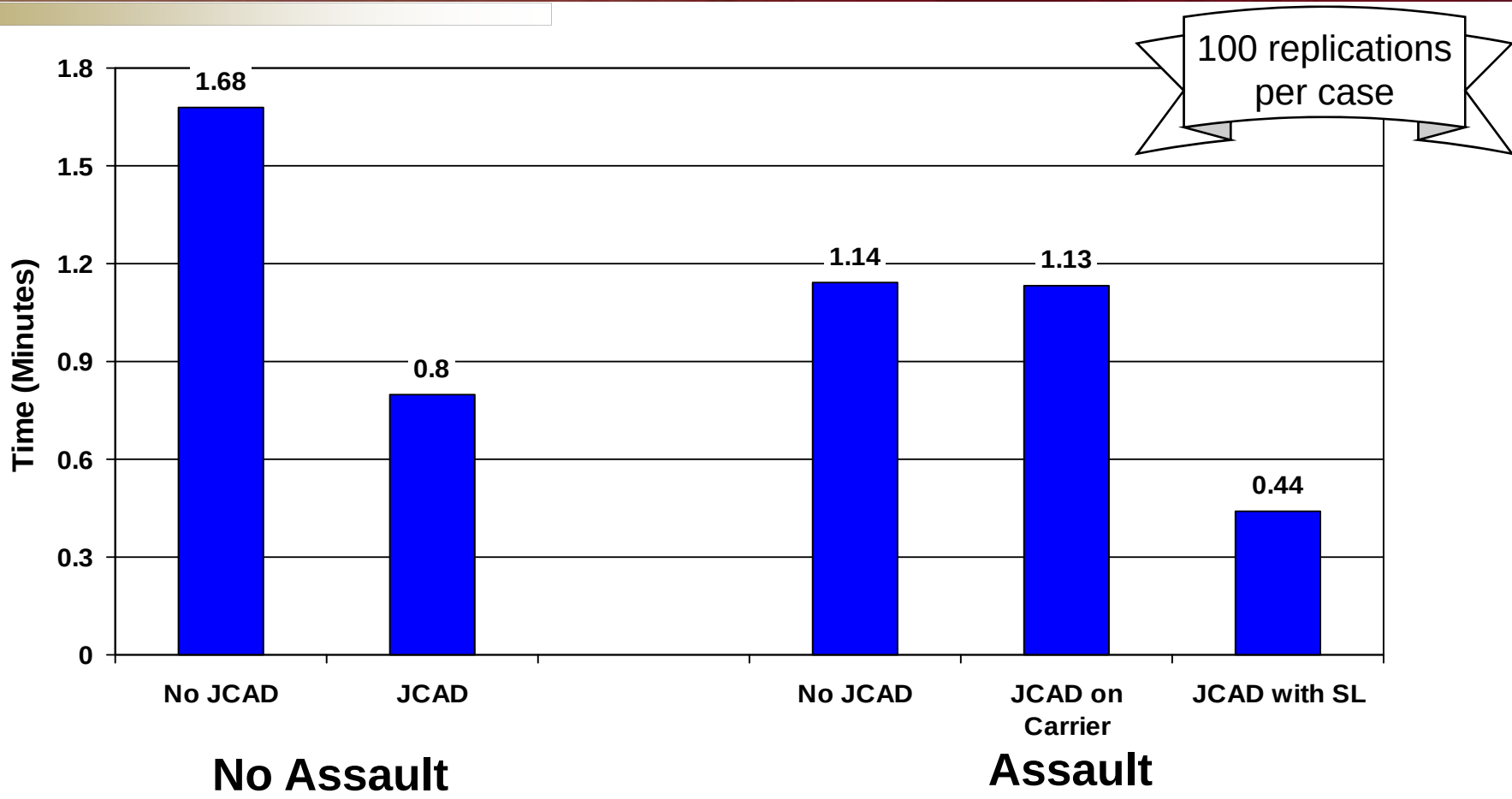
Results: Average Number BLUEFOR Experiencing at Least Initial Effects



- No Assault: Average number of BLUEFOR experiencing initial effects significantly* reduced
- Assault: No significant* reduction in the number of BLUEFOR experiencing initial effects except* when the Squad Leader has the JCAD

* 95% Confidence

Results: Average BLUEFOR CWA Exposure Time



- No Assault: Significant* Reduction (52%) with JCAD
- Assault: Significant* Reduction (61%) only with JCAD on Squad leader

* 95% Confidence

Conclusions

- **Successfully demonstrated ability to integrate chemical agent effects, soldier behaviors, chemical detector capabilities into IWARS combat simulation**
- **Better evaluation of CBD system operational effectiveness by allowing determination of quantitative MOEs**
- **Additional applications to operational planning, development of tactics, techniques, and procedures**

Backup Slides

Initialism List

- AEGL – Acute Exposure Guidance Level
- AMSAA – US Army Materiel Systems Analysis Activity
- BLUEFOR – Blue (friendly) Force
- CBD – Chemical and Biological Defense
- HPAC – Hazard Predition and Assessment Capability
- IED – Improvised Explosive Device
- IWARS – Infantry Warrior Simulation
- JCAD – Joint Chemical Agent Detector
- M&S – Modeling and Simulation
- MOE(s) – Measure(s) of Effectiveness
- MOPP – Mission-Oriented Protective Posture
- OBJ BLUE – BLUEFOR company objective
- OBJ SOX – Assaulting force's target
- OPFOR – Opposition (non-friendly) Force
- SME(s) – Subject Matter Expert(s)
- V&V – Verification and Validation